

Ecological control of forest pest: a new strategy for forest pest control

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Abstract: In comparison with integrated pest management and chemical control, the authors put forward a new strategy of forest pest control, named ecological control of forest pest (ECFP). This paper reviewed the development history, summarized the concept and principles of ECFP, discussed the technology and methods of ECFP, and evaluated the ECFP and its application conditions.

Keywords: Ecological control of forest pest (ECFP); Chemical control; Integrated pest management; Ecosystem management

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Introduction

Integrated pest management and chemical control have been the main strategies in controlling the forest pest so far, but the large amount of chemical insecticide has brought serious consequences. First, chemical insecticides pollute soil, air, water and leave insecticide residues in forestry by-products; Second, chemical insecticides indiscriminately kill both pests and natural enemies, thus destroying the natural balance of pest and its natural enemies and bringing more other pest and disease to occur; Third, pests are likely to develop resistance to insecticides when broad spectrum chemical insecticides are repeatedly used; Forth, the cost of chemical insecticides increases continually. Therefore, we should further explore the theories and methods for forest pest control (Chen *et al.* 1999).

A number of studies showed that serious biological disasters were closely related to the host individuals, colonies, plant vigor and healthiness of the ecosystem. Thus, it is necessary to work out new strategies on the basis of plant individuals, colonies and ecosystem. This is also the second important reason for further probing into the theories and methods of forest pest control.

In June 1992, the World Environment and Development Conference affirmed a new idea, sustainable development. In the background of the new idea, the concepts of sustainable agriculture and sustainable forestry were put forward in succession, and accordingly sustainable plant protection came to us also. From the 1990s up to now, scientists have brought forward many new ideas, such as sustainable pest management, sustainable pest control, forest health protection, etc., which aimed at protecting ecological environment, resources and human beings. Now a further demand is to have a new strategy of forest pest control on the basis of those ideas (Ge 1998).

In the past, people paid much more attention to the economic benefit than to the ecological function. On one hand, the former forest management methods resulted in overexploitation of the forest resources; on the other hand, little attention was paid to the regeneration of forest ecosystem. As a result, degradation of ecosystem structure and function occurred. Since the 1990s,

people have been paying more and more attention to exerting ecological function of forest ecosystem rather than pursuing its economic benefit, and the focus of forest management in China has been turned from producing timbers to supplying multifunctions (Shao 2001).

In 1998, Dr. Zhang Xingyao (Zhang 1998) put forward a new strategy, ecological control and genic control of forest pest, which is that the ecosystem is adjusted and controlled by using ecological factors and biological gene to become a status of stability and high productivity.

The basic principle of ecological control of forest pest is to take plants, pests, natural enemies and environment as a whole of substances, energy and information in the ecosystem. It focuses on exerting all the available factors in the system according to the basic principles of ecology, economics and natural cybernetics. The method of ecological control is to use various ecological factors including pest themselves reasonably to control the structure and function of ecosystem, and reach the goal of pest control—forestry sustainable development. From the points of latest theory and practice, it can be expected that the ecological control and genic control will become the important strategies of forest pest control in China.

Concept and characteristics of Ecological Control of Forest Pest (ECFP)

Connotation and concept of ECFP

The connotation of ECFP is aimed at the whole function of forest ecosystem. The method of ECFP, which mainly includes biological control (using bio-organism and other products), cultivation of resistant species, site preparation, as well as dynamic monitoring of pest, can help restricting the growth and development of pest and reaching the goal of balance of ecosystem. The usage of chemical fertilizer and insecticides should be reduced or replaced by using any other control measures. There are also some stages in the procession including system analyzing, integrating, optimizing, designing and implementing, etc. The final goal is to exert all kinds of beneficial functions of various bio-resources in the system.

Technology basis of ECFP— Ecosystem management

Ecosystem management, developed since the 1980s, has become an economic and environmental project on the basis of the natural sciences such as ecology and biology. It needs supports from society and economy.

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Because of the complexity and diversity of artificial measures of pest control, manager should paid more attention to afforestation technologies, such as mixed stand technique, planting technique, site preparation technique, fertilization technique, stand age structure, and integrated management technique.

The target of ecological control of forest pest is to regulate the relation between trees, forest pests and environment, and to keep a relative equilibrium of forest ecosystem and exert the multi-functions of forest ecosystem by using integrated and optimized afforestation measures (Sun *et al.* 2001).

The final goal of ECFP is to make forest health, which means the ecosystem can exert functions normally. A major principle in the World Environment and Development Conference in 1992 is to keep the health and integrity of global ecosystem. A healthy forest ecosystem is always stable and sustainable and can maintain its organized structure and autonomies, also can maintain its resilience including resistance to pest and recovery ability after it is damaged and disturbed.

The indexes for evaluating forest health mainly include plant growth vigor, organization, and resilience. The vigor is expressed by metabolism or primary productivity of the plants, organization is assessed according to the diversity and quantity of ecosystem components, and the resilience is appraised by the capacity of maintaining structure and function under stress. The system will "jump" into another state when its change exceeds its resilience. The biological stress factors involve disease, insect, and competitive plant in the forest ecosystem. From the point of view of ecosystem and human being's benefit, a healthy forest ecosystem is bound to maintain its complexity and stability and also can satisfy economy, ecological and societal requirements.

Characteristics of ECFP

There are many differences between ecological control and integrated management. The method of integrated management is to control the pest populations by adopting mainly chemical products. In contrast, ecological control is to regulate forest ecosystem through optimizing forest structure, improving forest site conditions and selecting appropriately cultivated techniques, etc. The target of ecological control is to keep forest ecosystem stable and healthy, thus avoiding forest damage from the pest. Integrated control, especially chemical control, disturbs the equilibrium due to killing both of the pest and natural enemies. In a word, ecological control is helpful or useful to the whole environment and ecosystem, whereas the integrated management and chemical control only to kill the pests as a target might be actually harmful to the whole ecosystem in the long run (Luo *et al.* 1999).

Rules of ECFP

Rule of ecosystem

ECFP also differs from chemical control and integrated management because it must follow the ecosystem rules. In the past, forest pest control was focused on just controlling populations of particular pests. People had little knowledge that change of a small system element may destroy the systematic structure and function and cause catastrophic effects on forest ecosystem, or even destroy the whole ecosystem. Actually some pests do little harm to the composition, structure and function of ecosystem; on the contrary, they are good for ecosystem diversity and health. It is necessary to think over the threshold value. Therefore, control

threshold values were put forward, such as economic threshold and ecological threshold (Gu *et al.* 2001).

Rule of association (or relativity)

It is well known that forest ecosystem is rather complex. ECFP has to focus on the relationships between pests and hosts, pests and ecosystem, ecosystem and environment. The system elements will change when the whole system changes, vice versa. So the harmonious forest ecosystem component is the base of a superior function of the whole ecosystem.

Rule of ecological balance

The bio-stability is a kind of dynamic balance. The forest ecosystem has a characteristic of stability and dynamic balance. Therefore, ECFP should unconditionally follow the rules of dynamic balance.

Rule of ecological niche

Each species has its own environmental condition, namely niche. The niche of every species has to be taken into consideration in selecting trees, making afforestation plans and controlling pests. Otherwise, the ecosystem will lose its balance and stability. The niche is one of the basic guarantees and measures to keep ecosystem balance and stability.

Rule of environment protection

One of the goals of ecological control is to protect the environment and reduce pollution, particularly pollution to the soil, air and aquatic ecosystem. The environment is the precious resources and material foundation on which the mankind and all the living forms exist. The environmental protection rules apply not only to the outside forest ecosystem but also to the inside one. In order to ensure a sustainable society and forestry, we have to obey the principle of protecting environment.

Rule of evolution

The relationship between two bio-elements of forest ecosystem is very complicated. In forest ecosystem evolution of element is a widespread phenomenon, which is determined by the adaptability and tolerance to adversity. So the ecological control should be also dynamic with spatial and temporal changes. Ecological control is closely relative to the adaptability of forest pests, hosts and host populations.

Rule of forest by-product safety

ECFP has to follow the rule of forest by-product safety. A lot of forest by-products are closely related to people's work and life, so ECFP should not harm them (Huang *et al.* 1999). Along with technical progress and the improvement of productivity level, people need more and more forest by-products. ECFP must ensure forest by-product safety. Certainly, the ecological control is the best available approach to reach this goal.

Rule of ecosystem stability

In the past, people always paid more attention to the economic benefits than to the ecosystem stability. However the basic condition of biology coexistence was destroyed, even ecosystem collapsed. Thus, the rule of ecosystem stability should be put in the first place for ensuring normal function and stability of the ecosystem.

Rule of ecosystem function

The top target of ECFP is to exert the multifunction of forest ecosystem including high productivity, economic benefits, ecological benefits and social benefits. Generally speaking, forest pest ecological control should keep the highest and the most harmonized functions. The long-term stability and balance of the ecosystem are the priority.

Rule of sustainability

Sustainable control to forest pest is a pursued goal by forest manager. ECFP can realize the goal of sustainable control of forest pest only if it follows the rules of stability, equilibrium and system. Therefore, it is necessary and urgent to carry out ecological control to forest pest. In addition, ecological control can make full use of ecosystem's self-regulated functions, so the effect of ECFP lasts longer than that of other pest control techniques (Luo *et al.* 1998).

Technique outline of ECFP (Zhang 2003)

Analysis and design of forest ecosystem

The goal of analysis and design is to put forward optimum measures of afforestation for controlling pests on the basis of the present technology and knowledge. The key step of analysis is to analyze the relationship between a measure and another measure and the relationship between an element and another element of the forest ecosystem.

Establishment of forest ecosystem

First, manager must follow the scheduled designs and plans, and think over the relation among host, pest and natural enemies, so as to control the forest pests under the lowest population. Second, manager must guarantee the quality of afforestation according to criterion of afforestation. Although some techniques used in establishment of forest ecosystem do not have obviously efficiency in a short term, they will fully exert action in the future.

Maintenance of forest ecosystem

Maintenance of forest ecosystem needs more time and investment in the process of ecological control of forest pest. It plays an important role in sustainable pest control of ecosystem. The technology processes include pest monitor, pest risk analysis, disaster forecast, measure design and plan implement.

Regeneration and reconstruction of forest ecosystem

The regeneration and reconstruction of forest ecosystem is the base of sustainable function of the forest ecosystem. Since the technology process of regeneration and reconstruction of forest ecosystem need shorter time in plantation than in natural forest and secondary forest, forest manager should pay more attention to plantation regeneration and reconstruction. When manager regenerate and reconstruct forest ecosystem, the relationship between characters of the next generation ecosystem and the last generation ecosystem should be considered. If the forest ecosystem health becomes worse due to soil degradation or pests during the regeneration and reconstruction of forest ecosystem, this ecosystem will lower its resistance to pests and eventually lose its stability.

Main measures of ECFP

Site control measure (Zeng 1996)

Many studies showed that site condition is closely related to the development of forest pest. Manager need control site condition for controlling pest development. For example, manager can kill pest by controlling illumination intensity, quantity of heat and water and so on. To plant right tree species on right site is the basic guarantee to keep ecosystem healthy, because healthy forest ecosystem have more resistance to pest. So the site condition had an immediate effect on occurrence and development of the forest pest disaster.

The site control method mainly includes soil preparation, fertilization, irrigating, weeding, loosing soil, etc.

Stand management

Any measures of stand management have a direct or indirect effect on the occurrence and development of forest pest. The management measures also affect the ecosystem function at least for one generation. So stand management measures are very important to control of forest pest.

The measures of stand management mainly include optimizing biological diversity, keeping stand health, distributing right the aboveground and underground space. Apparently the measures of stand management are to optimize the space structure of stands and to increase resistance and vigor of trees so as to indirectly control forest pest population.

Utilization and development of host resistance

Host resistance mainly includes induced resistance, damage tolerance and compensation.

Induced resistance is an important way of tree's evolution and exists broadly in plants and pest species. And induced resistance can be inherited to next generation.

Damage tolerance is an important physiology characteristic which tree forbear pest harm. Studying and improving tree's damage tolerance is very important to increase the stability of stands and ecosystem.

Compensation is a kind of tree's defense characteristic to pest and exists broadly in ecosystem. When tree is injured by pest, tree starts its compensation for recuperating the loss caused by pests.

Biological control

Biological control is one of the most important measures in ecological control and it is to use antagonistic interactions between pest and its natural enemy, including biological insecticides, biological fertilizer, natural enemy insects, pest pathogens, etc. The soil microorganisms play an important role in improving forest resistance to pest. And some researchers are clarifying the optimized root microenvironment which affects forest resistance to pest. Some studies showed that mycorrhizal fungi played a positive role in keeping forest ecosystem healthy and stable. Although biological control may affect stability and duration, substitute of local population, heredity regroup, gene flow, site factors, etc., it is a better measure than chemical control in control pollution.

Pheromone control

Pheromone control has been applied in practice since the 1960's. A great deal of volatile is released by plants and insects evidently affect insects' behavior. For example, insect sex

pheromone has been applied to control *Dendrolimus punctatus*, *Dendrolimus tabulaeformis*, *Paranthrene tabaniformis*, *Sesia sinensis*, *Cossus mongolicus*, *Lymantria dispar*, *Semiothisa cinerearia*, *Matsuococcus matsumurae*, *Dendroctonus valens*, *Diprion pini*, etc. But this technology is mainly used in monitoring, quarantining, identifying taxonomy of harmful insects, seldom in controlling, such as trapping, disturbing mating, etc. This technology has the advantages of minimum disturbance or damage to host in ecosystem. So we should pay great attention to the pheromone control combined with chemical ecology technology.

Regulation for emergency

In forest management, a succession of forest ecosystem could be forecasted and controlled, but some unpredictable pest disasters often occur due to the complexity of environmental and biological factors of the ecosystem. So it is necessary to establish a fast reaction mechanism and relevant regulating measures of emergency, which is an important part of forest pest disaster prevention. On the basis of forewarning, forecasting and monitoring of pest, the main regulative measures for emergency include quarantining and using biological pesticides with low-toxicity and high efficiency. In order to ensure the security and credibility of the measures, the test and feasibility analysis must be done before they are used.

Evaluation and application conditions of ecological control of forest Pest

Advantages of ECFP

The ecological control of forest pest has many advantages over the integrated pest management and chemical control in the following:

- (1) ECFP takes the health of forest ecosystem as targets.
- (2) Measure of ecological control is can thoroughly control pests. But manager must fully consider the effect of planting tree, management ecosystem and regeneration on forest diseases and insects;
- (3) The result of ecological control is better, although duration of ecological control result is longer than that of the general control method because many ecological factors are considered in control measure;
- (4) Measure of ECFP is easy to be implemented because of combining with forest management measure;
- (5) ECFP has the characters with low cost, high economic benefits and little negative effect;
- (6) Control range of ECFP is broader than that of other strategies.

Application conditions of ECFP

Ecological characteristic is the key of ECFP. It contains ecological characteristic of control objects, control measures, environment and management goals. The targets of control are decreasing pests; control measures are to use non-chemical products to improve site factors and bio-factors; the ecological characteristic of environment is to use pesticide which is not pollute environment; the ecological characteristic of management goal is to achieve all potential benefits and especial ecological benefit of the forest ecosystem.

Ecological control measure of forest pest overcomes many limitations of chemical control and biotic control and is more integrated and systematic.

Further studies on theory and application of ECFP will open up a new way for the object of health and sustainable function of forest ecosystem.

Ecological control measure of forest pest is applicable when people have advanced knowledge about forest ecosystem, practical management level and appropriate technology. Ecological control also needs better social, economic and natural conditions; otherwise it is very difficult to realize the self-regulation of ecosystem. Although ecological control of forest pest has more demands to managers and practitioners, and ecological control of forest pest needs better natural, social and economic conditions, it has attracted great attention because it has more merits than chemical control. Ecological control of forest pest will has a vast prospect for forest pest control in the future.

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